

Abstract Title Page

Title: Improving Student Learning of Ratio, Proportion, and Percent Problem Solving: A Replication Study of Schema-Based Instruction

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Abstract Body

(Limit =1000 words, Current = 1,218)

Background:

Ratio and proportional relationships, along with the interrelated topics of fractions, decimals, and percent provide a critical foundation for algebra (National Mathematics Advisory Panel, 2008). Solving even simple proportion problems is challenging for many children and adolescents (Adjage & Pluinage, 2007; Fujimura, 2001; Lamon, 2007; Lobato, Ellis, Charles, & Zbiek, 2010; Miyakawa & Winslow, 2009; Weinberg, 2002). A small number of studies have examined the efficacy of schema-based instruction (SBI), a multicomponent approach to teaching proportional problem solving. The studies of SBI, with roots in schema theory of cognitive psychology, research on expert problem solvers, and cognitive models of mathematical problem solving, have provided evidence of its promise in improving student learning (Jitendra et al., 2009; Jitendra, Star, Rodriguez, Lindell, & Someki, 2011; Jitendra, Star, Dupuis, & Rodriguez, 2013; Jitendra et al., 2015). However all of these studies relied on data from the Upper Midwest of the U.S, and what is needed is evidence that the efficacy of SBI generalizes to a range of students and teachers located throughout the country.

Focus of Study:

The purpose of this study was to replicate and extend the study of the SBI intervention conducted by Jitendra et al. (2015) that demonstrated impact in proportional problem solving for a homogeneous sample of Upper Midwest students and teachers who were predominantly White and middle class. While the importance of replication in enhancing external validity is a staple of educational methods textbooks, replications are rare in practice (Duncan, Engel, Claessens, & Dowsett, 2015; Yong, 2012) but badly needed (Makel & Plucker, 2014).

We chose to replicate this study in two geographically diverse locations (Northern Rocky Mountains and Southeast U.S.) that reflect a diversity of students and teachers across the factors of race, socio-economic status, and the percentage of English Language Learners. We posed the following research questions: What are the effects of the SBI intervention compared to business-as-usual instruction on students' proportional problem solving at immediate posttest and after 11 weeks as well as on students' general mathematical problem solving?

Setting and Population:

Students from 52 seventh-grade classrooms ($N = 1,379$) and their teachers ($J = 52$) from 30 middle schools in four school districts participated in the study. Student enrollment in the districts ranged from 33,899 to 203,439 students. The percent of minority students in the districts ranged from 25 to 59% with an average of 40%; the percent of students eligible for free or reduced price lunch in districts ranged from 30 to 60% with an average of 49%. We are currently in the process of obtaining student demographic data from the participating school districts.

Intervention:

A detailed description of SBI can be found in Author et al. (2015).

Research Design and Data Collection:

We used a randomized cluster design with longitudinal data. For each of the 52 teachers, one class of students was randomly selected to participate in the study. Each of the 52 teachers and their participating class was randomly assigned to one of two conditions: treatment or

control. In treatment classrooms SBI was implemented daily over 6 weeks, whereas students in the control condition received instruction on the same topics using their district-adopted textbook. All treatment teachers participated in 16 hours of professional development, approximately four weeks before the study period began.

Students' proportional problem solving (PPS) performance was tested on three occasions (pre, post, delayed posttest given 11 weeks after the intervention). The PPS has been validated and used in prior studies (e.g., Author et al., 2015, in press) and consist of 22 multiple-choice questions and four short-response items. Analyses focused on overall treatment vs. control comparisons. We assessed students' general mathematics problem solving using scores on the Process and Application subtest of the Group Mathematics Assessment and Diagnostic Evaluation (GMADE, Pearson Education, 2004). We also collected data on proportion problem solving instruction in the treatment (two observations per teacher) and control classes (one observation per teacher) by videotaping each teacher's class and then coding the extent to which the SBI treatment was implemented with fidelity as well as the implementation fidelity in control classes.

Data Analysis and Results:

Results indicated statistically significant differences between treatment and control groups on the total score for fidelity-of-implementation items, with treatment teachers implementing SBI elements with more fidelity than topics implemented by control teachers ($t(50) = 7.98, p < .001, g = 2.21$).

Preliminary inferential results used two-level (students nested within classrooms) hierarchical linear models fitted to each of the outcome variables (i.e., PPS posttest, PPS delayed posttest, GMADE posttest) to provide an initial assessment of the effect of the treatment. The treatment variable was the only classroom-level covariate and PPS pretest the only student-level covariate. The results (see Table 1) indicated statistically significant differences favoring SBI on the PPS posttest ($\gamma = 3.04, p < .001$), PPS delayed posttest ($\gamma = 1.72, p = .005$), and GMADE posttest ($\gamma = 1.40, p = .024$). Standardized effect sizes comparing the SBI and control conditions on the PPS posttest, PPS delayed posttest, and GMADE posttest were $g = 0.59, 0.35$, and 0.28 SDs, respectively. Subsequent analyses will include a predictor capturing differences in fidelity-of-implementation, predictors representing teacher and student demographic data, and explore student change over time and whether such change was impacted by the treatment.

Conclusions:

The preliminary results of this study are generally consistent with previous findings (Jitendra et al., 2009, 2011, 2013, 2015) that SBI enhances proportional problem solving. In both the present study and the original Jitendra et al. (2015) study students in SBI classrooms learned the content more effectively than control students. Also notable is that the effect size on the PPS posttest exceeded somewhat ($g = 0.59$ vs. 0.46) that obtained in Jitendra et al. (2015). We are encouraged that the effects in Jitendra et al. (2015) with a homogenous group of students appear to hold in the current study with a more geographically and demographically diverse sample of students.

Appendix A. References

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Appendix B. Tables

Table 1

<i>HLM Results by Outcome Measure</i>					
<i>Proportional Problem Solving Posttest</i>					
Fixed Effect	<i>Coefficient</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i>
Intercept	12.70	0.44	28.97	50	<.001
Treatment	3.04	0.61	4.99	50	<.001
Pretest	0.69	0.28	24.89	1240	<.001
Random Effect	<i>Variance</i>	<i>SD</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	4.11	2.03	386.76	50	<.001
Residuals	15.20	3.90			
<i>Proportional Problem Solving Delayed Posttest</i>					
Fixed Effect	<i>Coefficient</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i>
Intercept	12.62	0.42	30.23	50	<.001
Treatment	1.72	0.58	2.97	50	.005
Pretest	0.76	0.03	26.36	1177	<.001
Random Effect	<i>Variance</i>	<i>SD</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	3.60	1.90	319.39	50	<.001
Residuals	15.49	3.94			
<i>GMADE Process and Applications Posttest</i>					
Fixed Effect	<i>Coefficient</i>	<i>SE</i>	<i>t</i>	<i>df</i>	<i>p</i>
Intercept	12.48	0.44	28.62	50	<.001
Treatment	1.40	0.60	2.33	50	.024
Pretest	0.52	0.03	17.62	1213	<.001
Random Effect	<i>Variance</i>	<i>SD</i>	χ^2	<i>df</i>	<i>p</i>
Intercept	4.10	2.02	389.16	50	<.001
Residuals	13.70	3.70			